



FIELD TOUR GUIDE

RESPONSE OF BIODIVERSITY AND TIMBER
25 YEARS AFTER HERBICIDE USE



FOREST GROWTH
ORGANIZATION OF WESTERN CANADA

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This long-term herbicide effects field trial is a project of the Forest Growth Organization of Canada (FGrOW).

The project and the development of a field tour guide were funded by the Forest Resources Improvement Association of Alberta (FRIAA).

To learn more about FGrOW, visit
fgrow.ca/about



Recommended citation:
Mihajlovich, M., J. Nash and S. Odsen. 2021. Field tour guide: Response of biodiversity and timber 25 years after herbicide use. Forest Growth Organization of Western Canada (FGrOW). Hinton, AB, Canada. 44 pp.

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HOW TO USE THIS GUIDE

The use of chemical herbicides (primarily glyphosate) for competition control is a common practice for reforestation of harvested conifer stands in much of Alberta, yet it remains controversial for many. While there is an abundance of research that has focused on the short-term effects of herbicide use on both tree growth and non-tree vegetation, there is a notable knowledge gap on the long-term effects of herbicide use on regenerated forests.

The Forest Growth Organization of Western Canada (FGrOW) has addressed this gap by evaluating the long-term (25–40 years post-harvest) effects of herbicide use on both biodiversity and wood fibre production in regenerated blocks. These blocks were originally treated as part of the “Go-slow” herbicide adoption and monitoring process implemented in the mid-1990s in Alberta, and they include a minimum one-hectare untreated area within a cutblock treated with herbicide. Although the Go-slow program and its monitoring requirement have since ended, some installations remain in place, and sites for this study were selected from that pool.

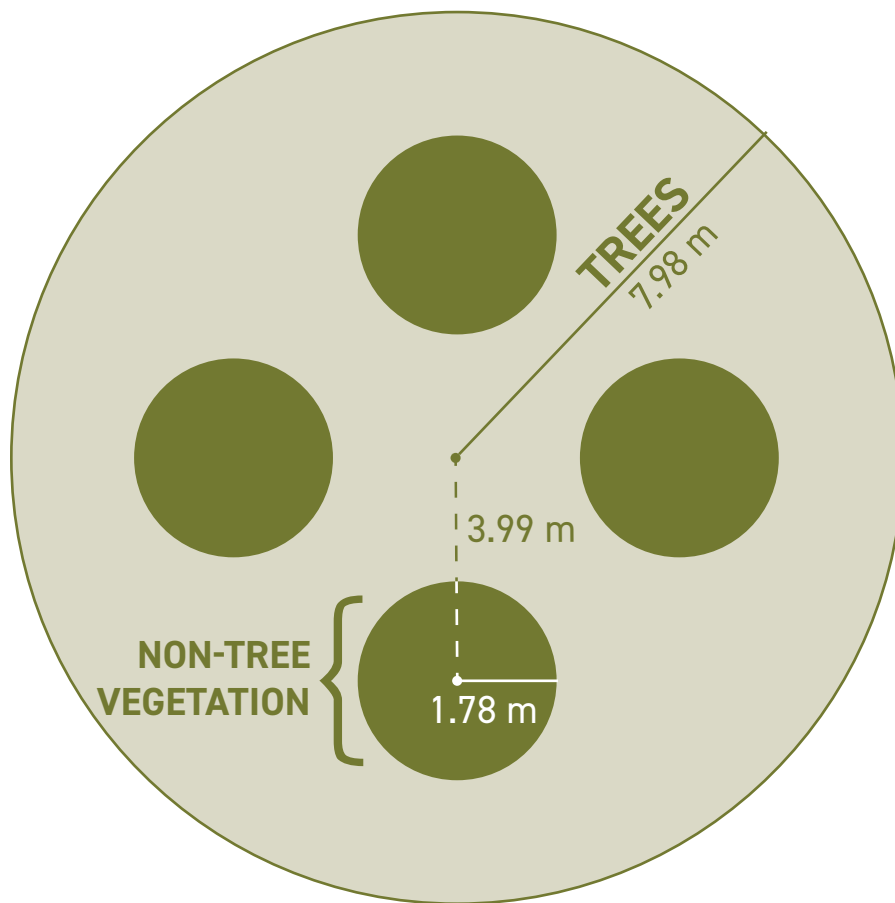
This guidebook is intended to facilitate guided and self-guided tours of the research sites and plots included in this study.¹ It provides directions to the young forest stands that were characterized for this project; for each, it summarizes the block history (from official reforestation treatment records) and differences in biodiversity and fibre volumes between treated and untreated portions of each block. Each site also includes a high-resolution aerial composite orthograph showing the untreated and treated portions of the block and the plot locations.

If you have any questions about the methods, findings or implications of these results, please visit fgrow.ca.

¹Site 3 was removed from the study after the untreated portion was disturbed by construction of an electrical transmission line. Site 4 was excluded from analyses due to a follow-up herbicide treatment on the untreated portion prior to remeasurement.

DATA COLLECTION

Three plots were randomly located in the treated and untreated portion of each cutblock for a total of six plots for each site. Trees were measured in each “main” plot. Non-tree vegetation (shrubs, herbs, mosses) was measured in four smaller subplots located systematically within the main plot.



Trees were counted and measured (e.g., diameter at breast height) in 7.98-m radius (0.02 ha) plots. These metrics were used to calculate fibre volume for each species.



Non-tree vegetation was identified to the species level (or, in the case of mosses, to the group level) in four 1.78-m radius subplots at each plot. Each subplot was located 3.99 m from the plot centre and at each cardinal direction. Vegetation cover was estimated to the nearest 1% for each species within each subplot, and these values were averaged at the plot level.

HOW BIODIVERSITY WAS MEASURED

An important objective of this project was to monitor biodiversity responses to herbicide application over an extended length of time. There are many different ways to quantify and compare biodiversity, and ecological studies typically use several methods to form a more complete picture. The following calculations were performed using cover estimates of non-tree vegetation species.

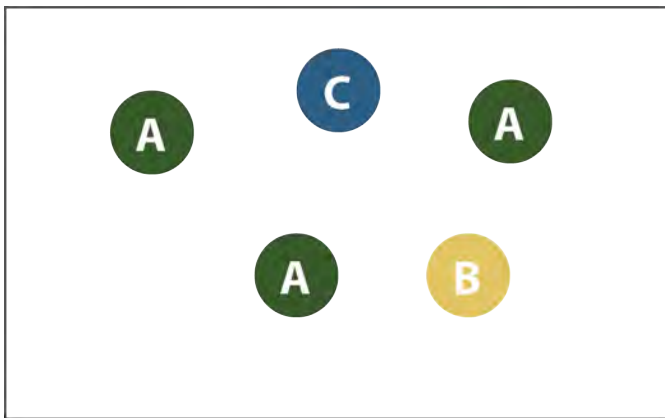
SPECIES RICHNESS

Species richness is the number of unique species observed, regardless of their abundance. Species richness is provided for each site. Forest floor mosses and wood mosses were each counted as a single species as they were not identified to the species level.

SHANNON-WIENER DIVERSITY INDEX

The Shannon-Wiener diversity index (H) is a common measure for species diversity. Values often range from 1.5 to 3.5 in most ecological studies. A lower value indicates that a site has fewer species and lower evenness (see below), while a higher value indicates that a site has more species and higher evenness (Fig. 1.).

Figure 1. Two example communities with different Shannon-Wiener diversity.

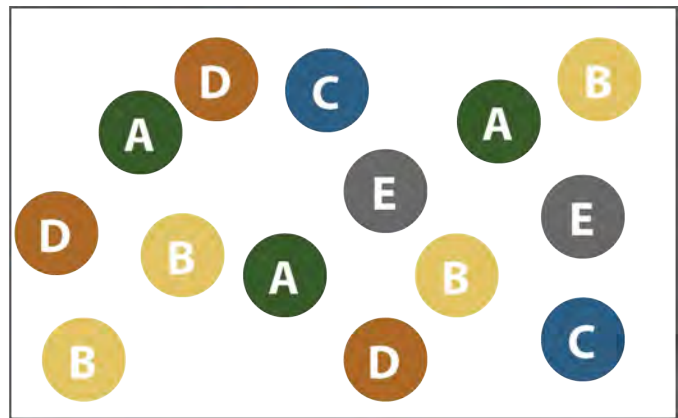


Example: low Shannon-Wiener diversity

Number of species = 3

Dominated by Species A

$H = 0.95$



Example: high Shannon-Wiener diversity

Number of species = 5

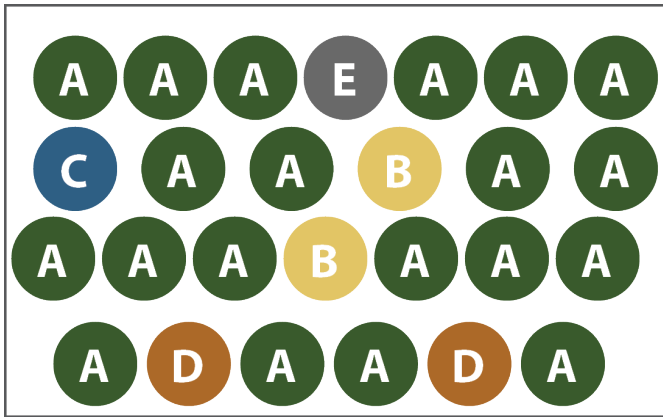
No species dominates

$H = 1.57$

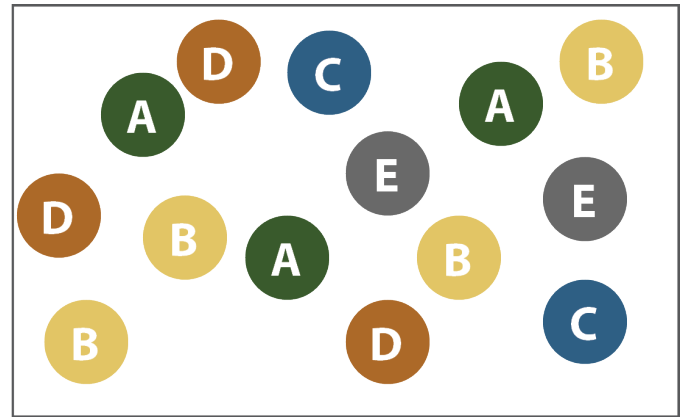
SPECIES EVENNESS

Evenness is an important concept in biodiversity. A site with low evenness may have many species, yet a few of these species are abundant and the others occur in low numbers. A site with high evenness has a more even distribution with many abundant species. This can have important implications if a disturbance or treatment changes the species community in such a way that one or two species (e.g., grasses or weeds) dominate the site. Evenness values can range from 0 to 1 (Fig. 2).

Figure 2. Two example communities with different evenness.



Example: low evenness
 Number of species = 5
 Dominated by Species A
 $E = 0.53$



Example: high evenness
 Number of species = 5
 No species dominates
 $E = 0.98$

CHANGES TO INDICATOR SPECIES

All of the monitored sites had similar soil moisture and soil nutrient conditions, and indicator species of these conditions were selected according to Alberta's ecosite field guides for the Lower Foothills: low bush-cranberry, wild red raspberry, wild sarsaparilla, bracted honeysuckle, dewberry, tall lungwort and oak fern. Forest floor mosses (feathermosses) were also included because of field observations of a strong treatment response.

Differences in cover of these indicator species were statistically tested and the results are presented at the project level. Significant changes in indicator species cover may indicate changes to the edaphic conditions arising from silviculture activities (site preparation, herbicide treatments and planting), specifically to the available soil moisture and/or nutrients.

REPORTING WITH AND WITHOUT MOSSES (BRYOPHYTES)

In the field, the treated portions were consistently observed to have higher moss cover. There was concern that analyses of the non-tree vegetation may be sensitive to moss cover and fail to clearly illustrate whether other species did or did not change. To address this concern, changes to diversity indices (H and E) were calculated with and without mosses. Where changes were observed with mosses but not without them, it indicates that mosses were the main non-tree vegetation type affected by the treatments.

Mean values for diversity (H) and evenness (E) of each site are presented using bar charts, and an appendix contains a full table with the mean values and standard deviations of these indices. Statistical analysis of these results will be included in an upcoming manuscript that will provide a deeper exploration of the project findings.

SUMMARY OF FINDINGS

TREE FIBRE VOLUME CHANGE

For each site, the percent change in tree fibre volume was calculated as $(Treated\ volume - Untreated\ volume) / Untreated\ volume$. This change in tree fibre volume has been summarized for:

- merchantable conifer species (white spruce and lodgepole pine),
- merchantable deciduous species (trembling aspen),
- all conifer species (white spruce, lodgepole pine and balsam fir),
- all deciduous species (trembling aspen, white birch and balsam poplar), and
- all tree species.

PROJECT-LEVEL FINDINGS: OVERSTORY TREES

Strong differences were observed in tree volumes between treated and untreated areas. Without exception, deciduous tree volumes were much lower (often approaching a 100% decrease) in treated plots, and conifer tree volumes increased by as much as 550%. These differences were driven largely by merchantable species in most sites.

NON-TREE VEGETATION BIODIVERSITY

Biodiversity of non-tree vegetation was assessed in four ways:

1. Species richness of each site, which is simply the number of unique species observed.
2. The Shannon-Weiner diversity index (H), which indicates higher diversity at higher values.
3. Species evenness (E): an evenness value of "1" indicates the same number of each species (i.e., perfect evenness), while a value closer to zero indicates dominance by one or a few species.
4. Project-level changes in cover of eight indicator species or species groups: low bush-cranberry, wild red raspberry, wild sarsaparilla, bracted honeysuckle, dewberry, tall lungwort, oak fern and feathermosses.

Shannon-Wiener diversity and evenness are reported using bar charts for each site summary. A table with mean values and standard deviations for each site is provided in the appendix. These results are reported with and without mosses. In the field, treated plots were observed to have higher moss cover compared with the untreated portion. Analyses including mosses therefore indicate the overall change in non-tree vegetation, while analyses that exclude mosses may reveal any underlying changes to non-moss species that may otherwise have been obscured.

PROJECT-LEVEL FINDINGS: NON-TREE VEGETATION

The most consistent difference was higher feathermoss cover in treated areas than in untreated areas. While this project was not designed to test the effect of overstory trees on understory vegetation, higher conifer tree volumes in the treated portions are a likely ecological explanation for the increased feathermoss cover.

Species richness and diversity indices of non-tree vegetation varied among treated and untreated areas: at some sites differences were quite small, while at others they were comparatively large. However, the change was not consistent, with diversity indices increasing in the treated portions of some sites and decreasing at others. This was true both including and excluding mosses, which appeared to drive differences at some sites but not at others.

Of the pre-determined indicator species, feathermoss percent cover on average increased by 23 in treated plots, while wild sarsaparilla, oak fern and low bush-cranberry had statistically significant but very small decreases in percent cover (<5) in treated plots. There were no significant differences in percent cover of bracted honeysuckle, dewberry, tall lungwort or wild red raspberry.

Taken together, these results reveal that apart from increased feathermoss cover, there were no detectable long-term differences in non-tree vegetation diversity indices associated with herbicide treatments. The low number of long-term monitoring sites available for re-measuring is an important limitation to our ability to draw strong conclusions, yet the absence of a clear, consistent increase or decrease in the treated portions suggests that the long-term impacts of herbicides on non-tree vegetation are small.

Site-level findings (diversity indices and tree volumes) are presented for each site within this guidebook.

KEY FINDINGS

- The strongest effect of the herbicide treatments was a change in overstory tree composition as demonstrated by changes in fibre volume.
- Species richness increased in the treated portions of half the sites and decreased in the other half. In a small number of sites the difference was large, but in most richness changed by ± 1 to 4.
- Differences in diversity and evenness between the untreated and treated portions were highly variable. Diversity and/or evenness declined in the treated portions of some sites and increased in others; at some sites these differences were quite large while at others they were small to negligible.
- Frequently, high levels of variability within the treated or/and untreated portions obscured the effects of treatment on the plant community. When differences were large they may indicate an effect attributable to treatment.

SITE 1

EFFECTS DEMONSTRATED

Herbicide treatments had a strong positive effect on species richness, a minimal effect on biodiversity indices of non-tree species, and a strong effect on fibre volumes and tree composition.

- Species richness increased from 19 species in the untreated portion to 26 in the treated portion (change = +7).
- Species diversity (H) slightly decreased in the treated portion, moreso when mosses were excluded from the calculation. This finding suggests that at Site 1, the understory vegetation community beyond mosses became slightly less diverse following treatment. Changes in evenness (E), however, were negligible.
- Conifer volumes increased by over 500%, while deciduous volumes decreased by 100%. The overall volume of all tree species decreased by 30%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Travel via Highway 32 and the Kidney Lake Road.

1. Take Highway 43 west from Whitecourt to Highway 32.
2. Turn north onto Highway 32.
3. Travel 15.7 km on Highway 32 to the Kidney Lake Road.
4. Turn east onto the Kidney Lake Road.
5. Travel 13.0 km on the Kidney Lake Road to a minor oilfield road.
6. Turn south onto the minor oilfield road.
7. Travel 5.8 km to Site 1.

COORDINATES

LAT/LONG (WGS 84)

Latitude	N54° 26.679'
Longitude	W115° 17.926'

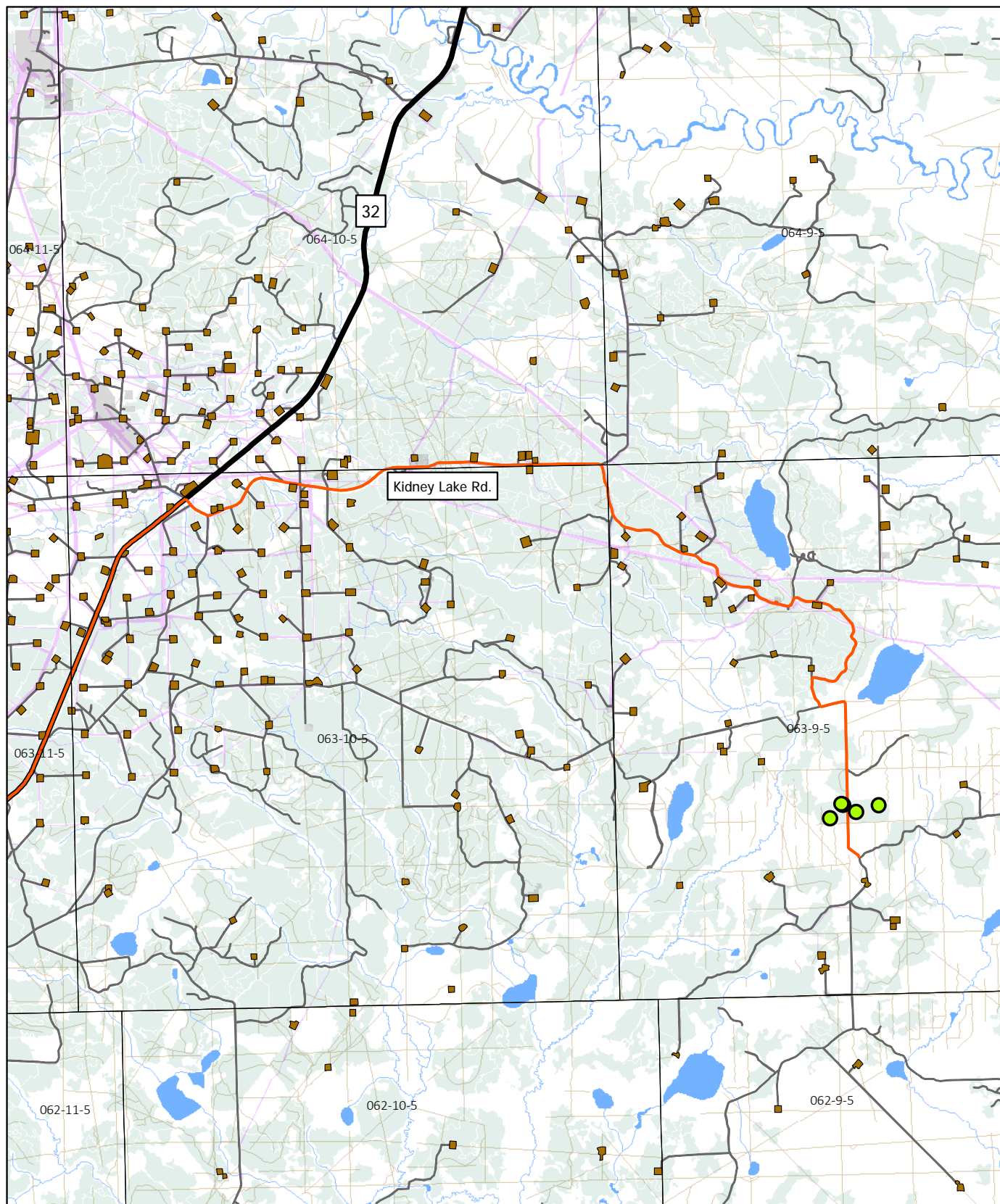
UTM (NAD 83)

Northing	6034328
Easting	610318
Zone	11N

ATS

Section	16
Township	63
Range	9
Meridian	W5

Site-1 Access



NAD83 UTM11N |
Township-Range-Meridian Grid



Plots



Well Block



Cutblock



Industrial Site



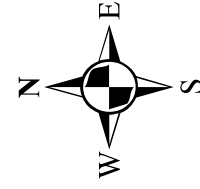
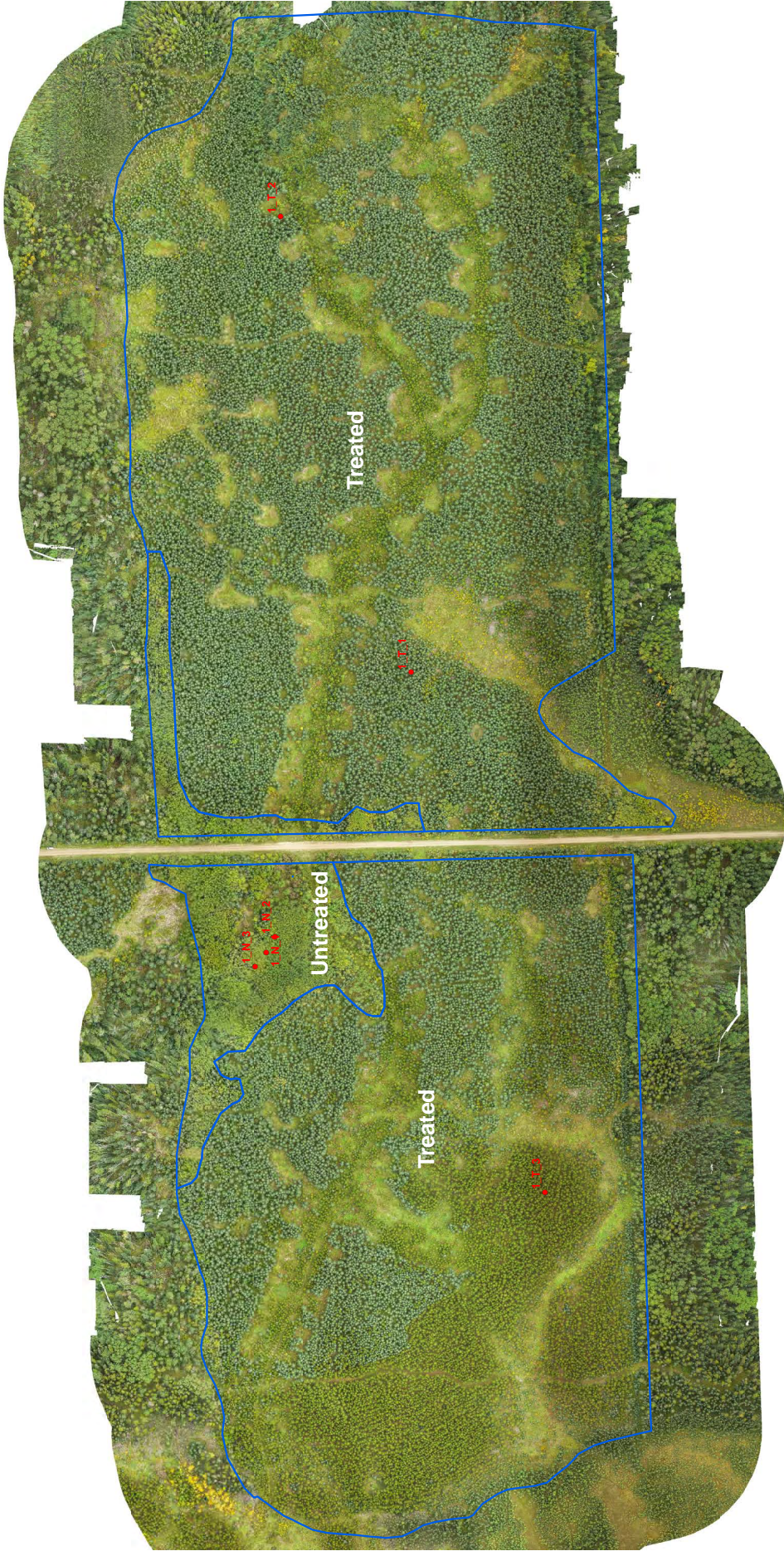
Pipeline



Road



Cutline



Herbicide Site-1

Photo Date: Sep 6, 2019

Ground Sampling Distance: 3.3 cm

Number of Photos: 820

3D Densified Points: 21,600,000

Scale 1:2,400



BLOCK HISTORY

Harvested by:
Blue Ridge Lumber Ltd.

Year harvested:
1995/96

Age at sampling:
24 years

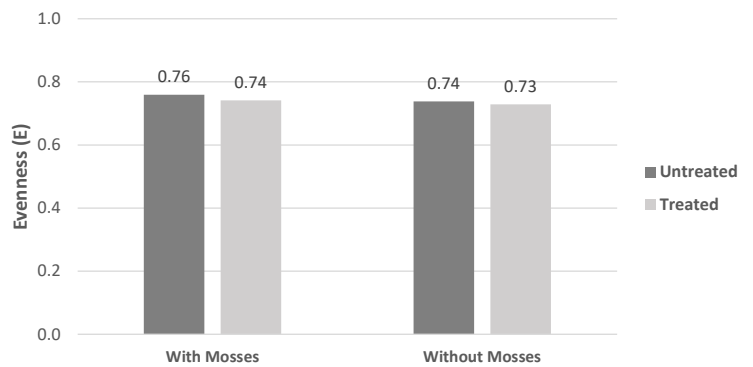
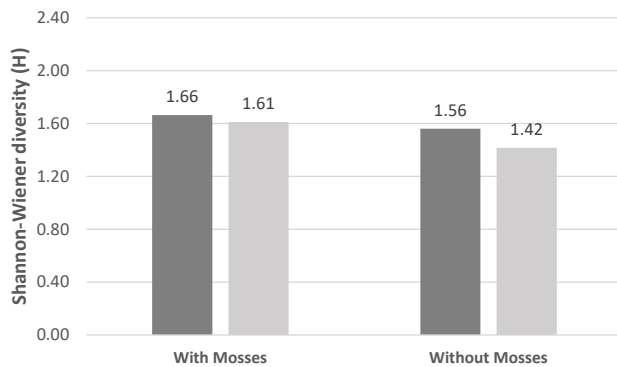
"NA" indicates no data.

"-" indicates no treatment.

Gray indicates remedial/follow-up treatments

		TREATED		UNTREATED	
SITE PREPARATION	1996		DIPO		DIPO
	2003		Mound (9 ha)		-
	2004		Plough (1.5 ha)		-
PLANTING STOCK	1996	Species	Sw/Pl		Sw/Pl
		Type	Plant		Plant
		Size	Bareroot		Bareroot
		Density	1461		1461
	2004	Species	Pl		Pl
		Type	Plant		Plant
		Size	410-Cu		410-Cu
		Density	NA		NA
TENDING	1997	Product	Glyphosate		-
		Rate	2136		-
		Method	Aerial		-
	2000	Product	Glyphosate		-
		Rate	2136		-
		Method	Aerial		-
	2005	Product	Glyphosate		-
		Rate	2136		-
		Method	Aerial		-

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
% change ¹	549%	-100%	514%	-100%	-30%

¹ % change = (Treated - Untreated volumes)/Untreated volume

SITE 2

EFFECTS DEMONSTRATED

Herbicide treatments had a small effect on species richness, a positive effect on biodiversity indices of non-tree species, and a strong effect on coniferous and deciduous fibre volumes.

- Species richness increased from 22 species in the untreated portion to 24 in the treated portion (change = +2).
- Species diversity (H) and evenness (E) increased in the treated portion compared with the untreated portion. This increase remained evident when mosses were excluded, suggesting that the remaining non-tree species became more diverse and even in the treated portion of Site 2.
- Conifer volumes increased by 200% or more in the treated portion. Deciduous volumes substantially decreased (98%) in the treated portion. Overall volume of all tree species decreased by 50%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Travel via Highway 32 and oilfield roads.

1. Take Highway 43 west from Whitecourt to Highway 32.
2. Turn north onto Highway 32.
3. Travel 10.6 km to major oilfield road.
4. Turn right onto major oilfield road.
5. Travel 2.3 km on major oilfield road.
6. Turn right (east) onto oilfield road. (This will feel like going straight as major road veers north (left).)
7. Travel 2.9 km on oilfield road.
8. Turn right (east) onto oilfield road. (Again, this will feel like going straight as major road veers north (left).)
9. Travel 2.9 km to Site 2.

COORDINATES

LAT/LONG (WGS 84)

Latitude	N54° 27.714'
Longitude	W115° 21.884'

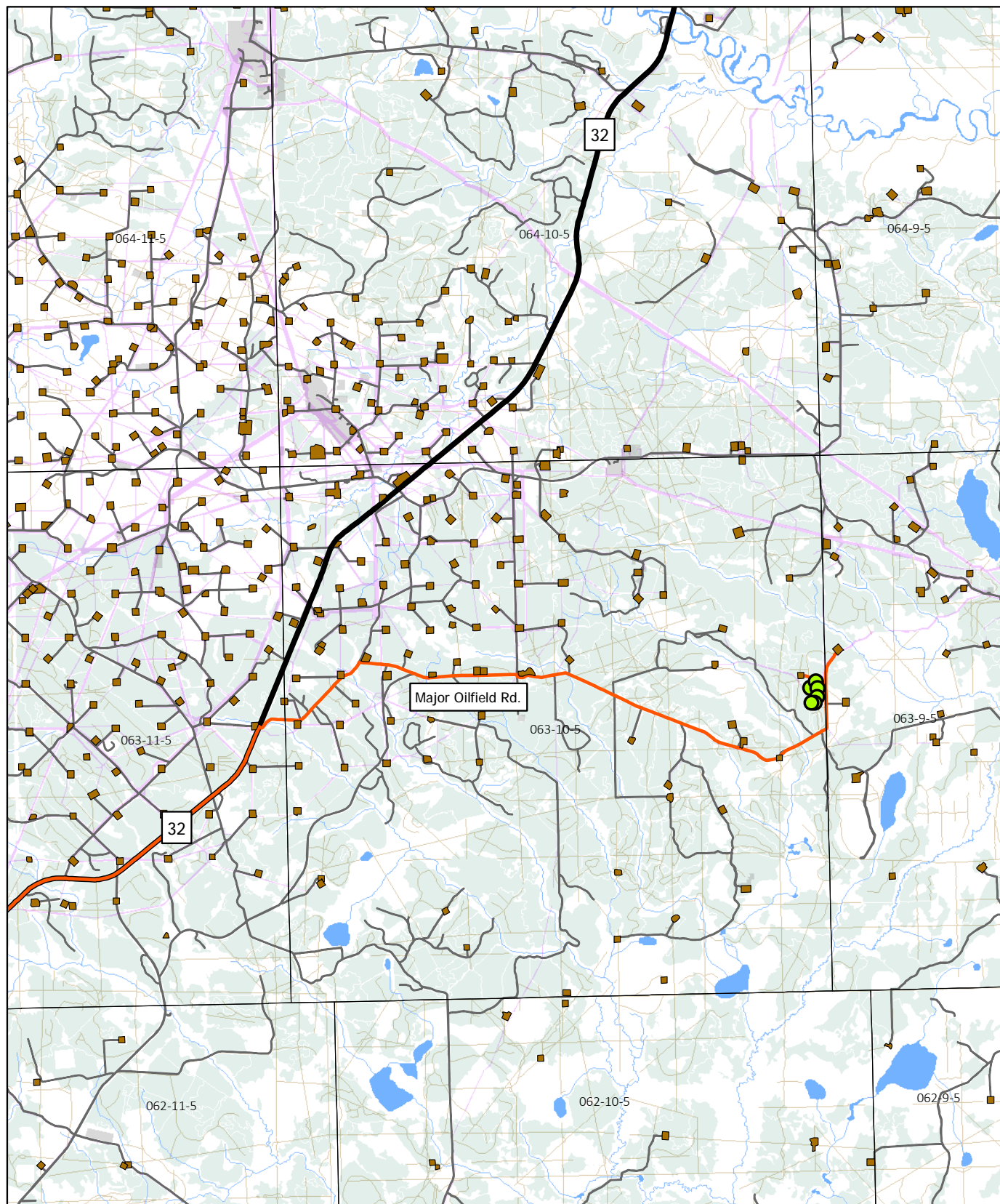
UTM (NAD 83)

Northing	6036145
Easting	605996
Zone	11N

ATS

Section	24
Township	63
Range	10
Meridian	W5

Site-2 Access



NAD83 UTM11N |
Township-Range-Meridian Grid



Plots



Cutblock



Pipeline



Road



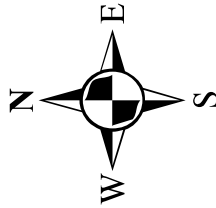
Well Block



Industrial Site



Cutline



Herbicide Site-2

Scale 1:2,200



Photo Date: Sep 6, 2019
Ground Sampling Distance: 3.1 cm
Number of Photos: 512
3D Densified Points: 58,500,000

BLOCK HISTORY

Harvested by:
Blue Ridge Lumber Ltd.

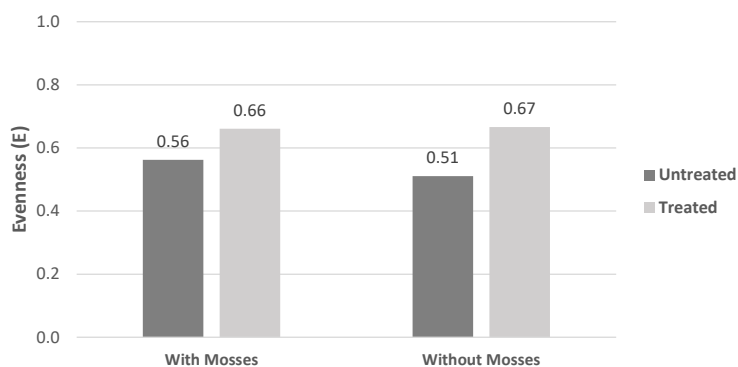
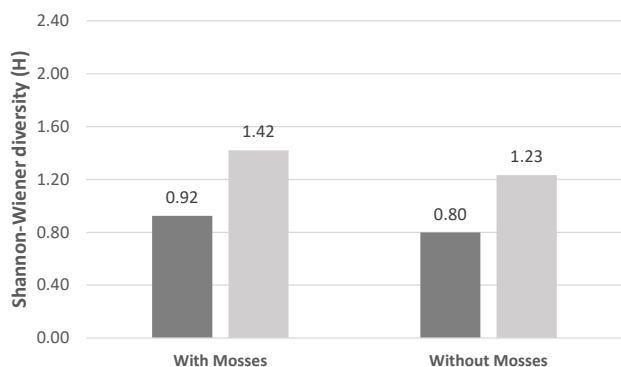
Year harvested:
1979/80

Age at sampling:
40 years

		TREATED		UNTREATED	
SITE PREPARATION		1980		Plough	Plough
PLANTING STOCK	1980	Species	Sw	Sw	
		Type	Plant	Plant	
		Size	Unknown	Unknown	
		Density	1555	1555	
TENDING	1990	Product	Hexazinone	-	
		Rate	Unknown	-	
		Method	Ground	-	
	2003	Product	Motor-manual	Motor-manual	
		Rate	NA	NA	
		Method	NA	NA	

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
% change ¹	256%	-98%	199%	-97%	-50%

¹ % change = (Treated - Untreated volumes)/Untreated volume

SITE 5

EFFECTS DEMONSTRATED

Herbicide treatments had a small effect on species richness, a minimal effect on biodiversity indices of non-tree species, and a strong effect on conifer and deciduous volumes.

- Species richness decreased from 28 species in the untreated portion to 24 in the treated portion (change = -4).
- Species diversity (H) decreased slightly in the treated portion, both with and without mosses included in the calculation.
- Evenness (E) of non-tree vegetation, in contrast, slightly increased in the treated portion both with and without mosses included in the calculation.
- Conifer volumes more than doubled and deciduous volumes decreased by over 80% in the treated portion. The overall volume of all tree species increased by 19%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Travel via Highway 43 and Secondary Highway 947.

1. Turn south off Highway 43 onto Secondary Highway 947.
2. Travel 29.9 km on Secondary Highway 947 (past SemCams South Kaybob plant).
3. Turn west onto minor oilfield road.
4. Travel 2.3 km on minor road, then turn left onto similar grade of road.
5. Travel 2.8 km to Site 5.

COORDINATES

LAT/LONG (WGS 84)

Latitude	N54° 04.131'
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Longitude	W116° 41.722'
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UTM (NAD 83)

Northing	5991224
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Easting	519935
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Zone	11N
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ATS

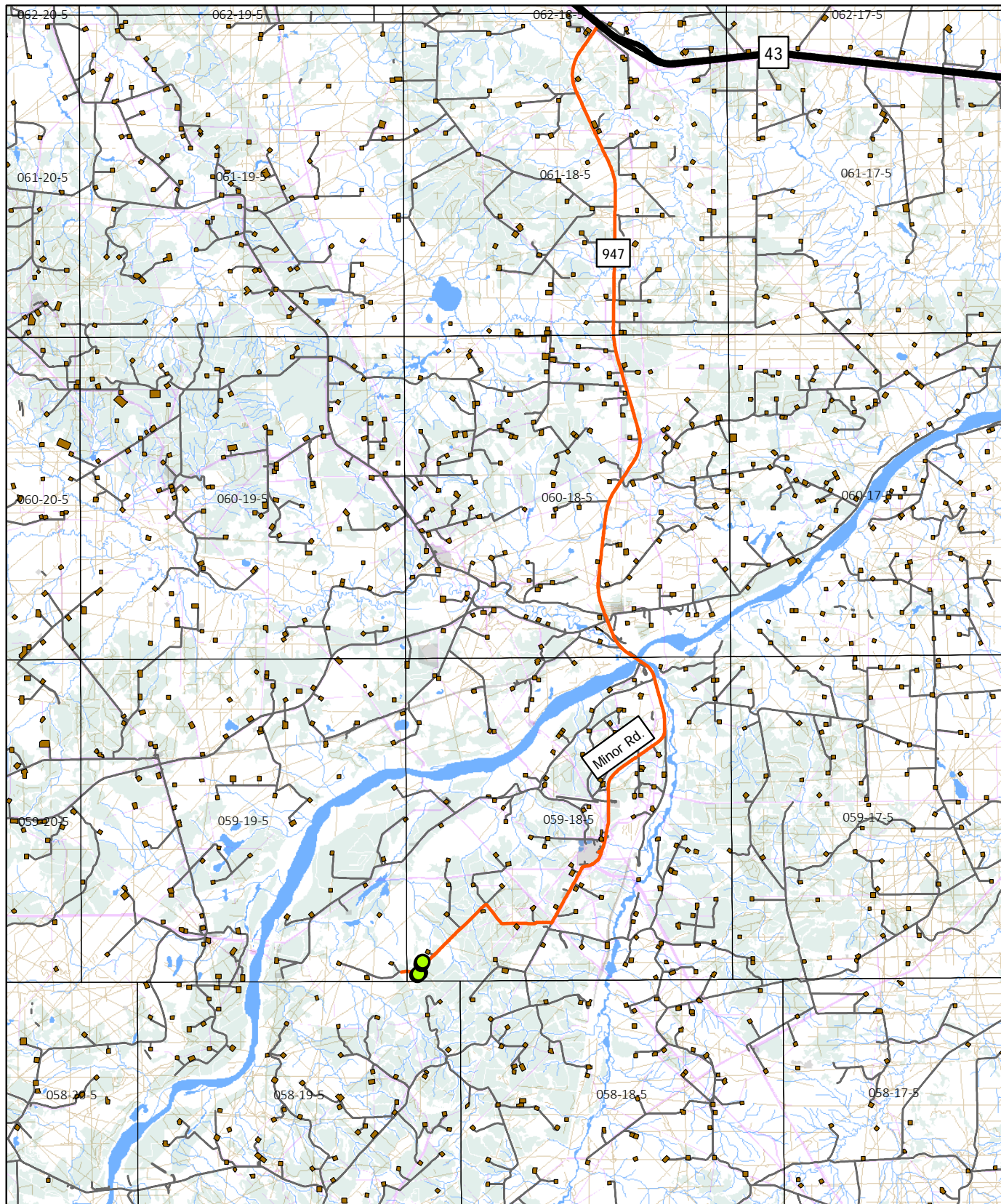
Section	6
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Township	59
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Range	18
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Meridian	W5
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Site-5 Access



NAD83 UTM11N |

Township-Range-Meridian Grid



Plots



Cutblock



Pipeline



Road



Well Block



Industrial Site

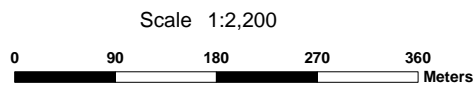


Cutline



Photo Date: Sep 5, 2019
Ground Sampling Distance: 2.8 cm
Number of Photos: 974
3D Densified Points: 31,700,000

Herbicide Site-5



BLOCK HISTORY

Harvested by:
ANC Timber Ltd.

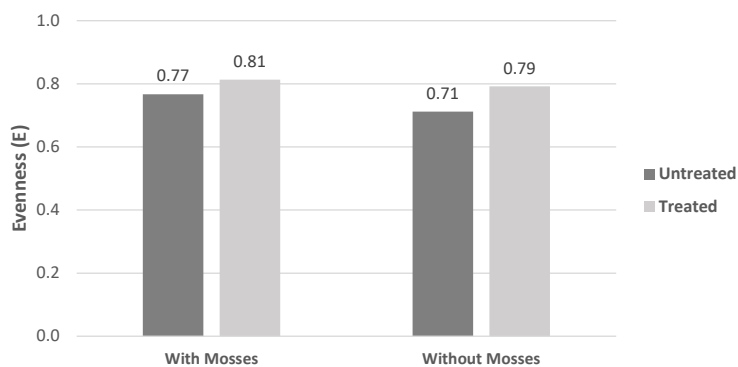
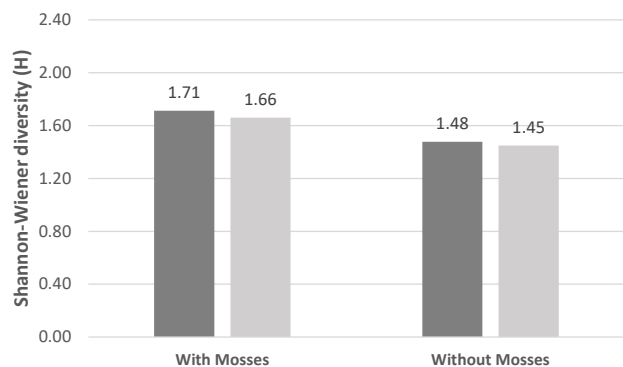
Year harvested:
1989/90

Age at sampling:
30 years

		TREATED	UNTREATED
SITE PREPARATION	1990	Disk	Disk
PLANTING STOCK	1991	<i>Species</i>	Sw
		<i>Type</i>	Plant
		<i>Size</i>	313C
		<i>Density</i>	1421
TENDING	1994	<i>Product</i>	Glyphosate
		<i>Rate</i>	1424
		<i>Method</i>	Aerial

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
<i>% change¹</i>	143%	-89%	134%	-87%	19%

¹ % change = (Treated - Untreated volumes)/Untreated volume

SITE 6

EFFECTS DEMONSTRATED

Herbicide treatments had strong negative effect on species richness, a negative effect on biodiversity indices of non-tree species, particularly diversity (H), and a strong effect on deciduous tree volumes.

- Species richness decreased from 36 species in the untreated portion to 22 in the treated portion (change = -14).
- Species diversity (H) decreased more substantially in the treated portion than the other sites. This decline was present both with and without mosses in the calculation, indicating that non-tree species other than mosses had lower diversity in the treated portion.
- Evenness (E) of non-tree vegetation also declined in the treated portion, but this change was much smaller than the change in diversity, suggesting that a reduced number of species—rather than increasing dominance of a small number of species—drove much of the change in diversity (H).
- This was one of the few sites with a smaller change in conifer volumes (an increase of just over 35%) in treated plots. Deciduous volumes, however, decreased by 100% in the treated portion. Total tree volume decreased by 49%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Travel via Highway 43, Secondary Highway 947 and ANC Resources Road.

1. Turn south off Highway 43 onto Secondary Highway 947.
2. Travel 18.9 km south on Secondary Highway 947.
3. Turn west onto ANC Resources Road.
4. Travel 23.3 km on ANC Resources Road to Site 6.

[Note: from Site 6, continue to Site 7]

Note: Plot number 3 from the untreated portion of Site 6 was found to have been treated with herbicide in 2006. A new plot was established in a random location in the remaining area of the untreated portion that had not been treated.

COORDINATES

LAT/LONG (WGS 84)

Latitude N54° 06.605'

Longitude W116° 55.764'

UTM (NAD 83)

Northing 5995772

Easting 504615

Zone 11N

ATS

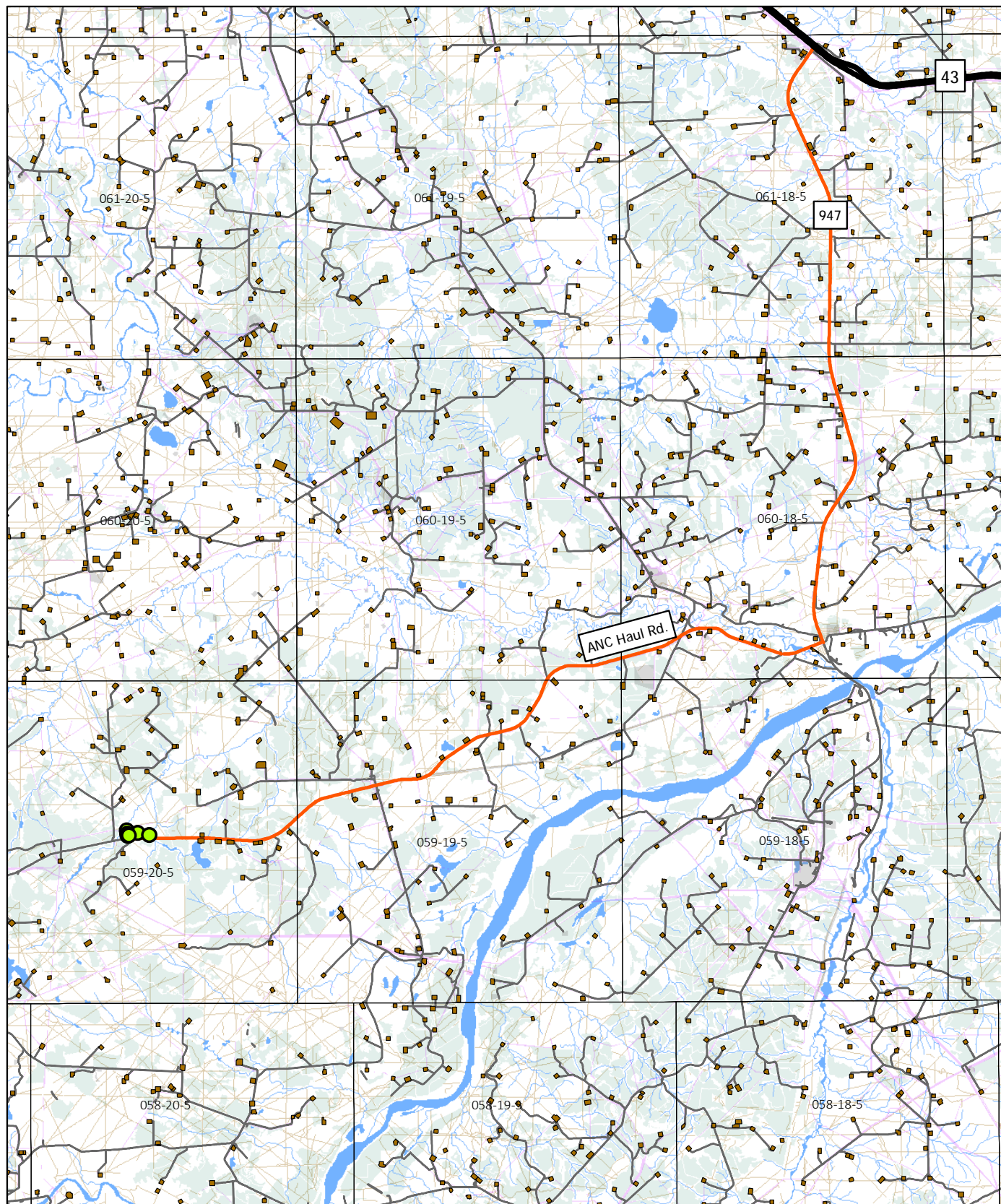
Section 21

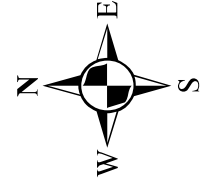
Township 59

Range 20

Meridian W5

Site-6 Access





Herbicide Site-6

Photo Date: Sep 5, 2019

Ground Sampling Distance: 3.1 cm

Number of Photos: 573

3D Densified Points: 17,800,000

Scale 1:2,000



BLOCK HISTORY

Harvested by:
Blue Ridge Lumber Ltd.

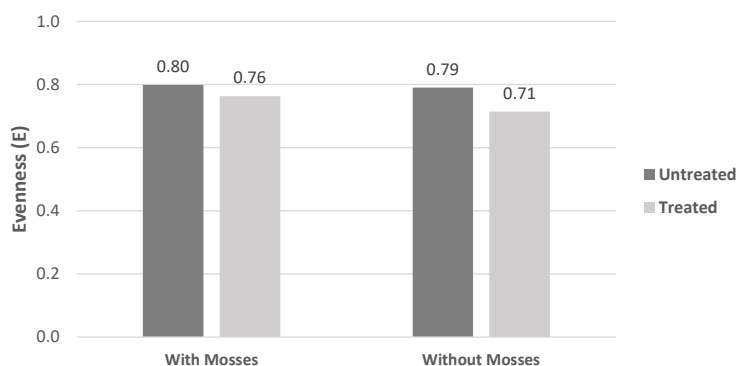
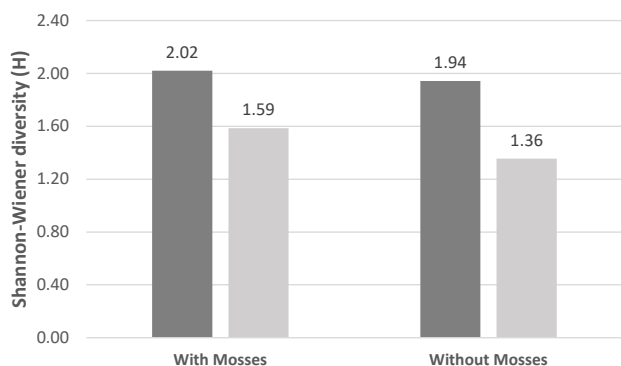
Year harvested:
1997/98

Age at sampling:
22 years

		TREATED	UNTREATED
SITE PREPARATION	1998	Mound	-
PLANTING STOCK	1998	Species	Pl/Sw/Sb
		Type	Plant
		Size	S410
		Density	1650
TENDING	1999	Product	Glyphosate
		Rate	2136
		Method	Aerial
	2006	Product	Glyphosate
		Rate	2136
		Method	Aerial

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
% change ¹	36%	-100%	37%	-98%	-49%

¹ % change = (Treated - Untreated volumes)/Untreated volume

SITE 7

EFFECTS DEMONSTRATED

Herbicide treatments had a small effect on species richness, a minimal effect on biodiversity indices of non-tree species, and a strong negative effect on deciduous tree fibre volumes.

- Species richness increased from 30 species in the untreated portion to 33 in the treated portion (change = +3).
- Species diversity (H) and evenness (E) of non-tree vegetation changed very slightly or not at all between the treated and untreated portions. Diversity slightly increased in the treated portion, and evenness slightly decreased (and did not change when mosses were excluded).
- Conifer volumes more than doubled in the treated portion. Deciduous volumes substantially decreased by 100% in the treated portion. Overall volume of all tree species decreased by 35%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Directions from Highway 43:

Travel via Highway 43, Secondary Highway 947 and ANC Resources Road.

1. Turn south off Highway 43 onto Secondary Highway 947.
2. Travel 18.9 km south on Secondary Highway 947.
3. Turn west onto ANC Resources Road.
4. Travel 23.3 km on ANC Resources Road to Site 6.

Directions from Site 6:

5. Travel a further 11.3 km west on ANC Resources Road (total distance travelled from Secondary Highway 947 = 34.6 km).
6. Turn south onto oilfield road.
7. Travel 2.5 km on oilfield road. Then stay left (southeast) onto another oilfield road. (This may be the only option.)
8. Travel 5.1 km on oilfield road, then turn north onto wellsite road. Travel to gate on wellsite road.

COORDINATES

LAT/LONG (WGS 84)

Latitude N54° 02.076'

Longitude W117° 03.105'

UTM (NAD 83)

Northing 5987372

Easting 496610

Zone 11N

ATS

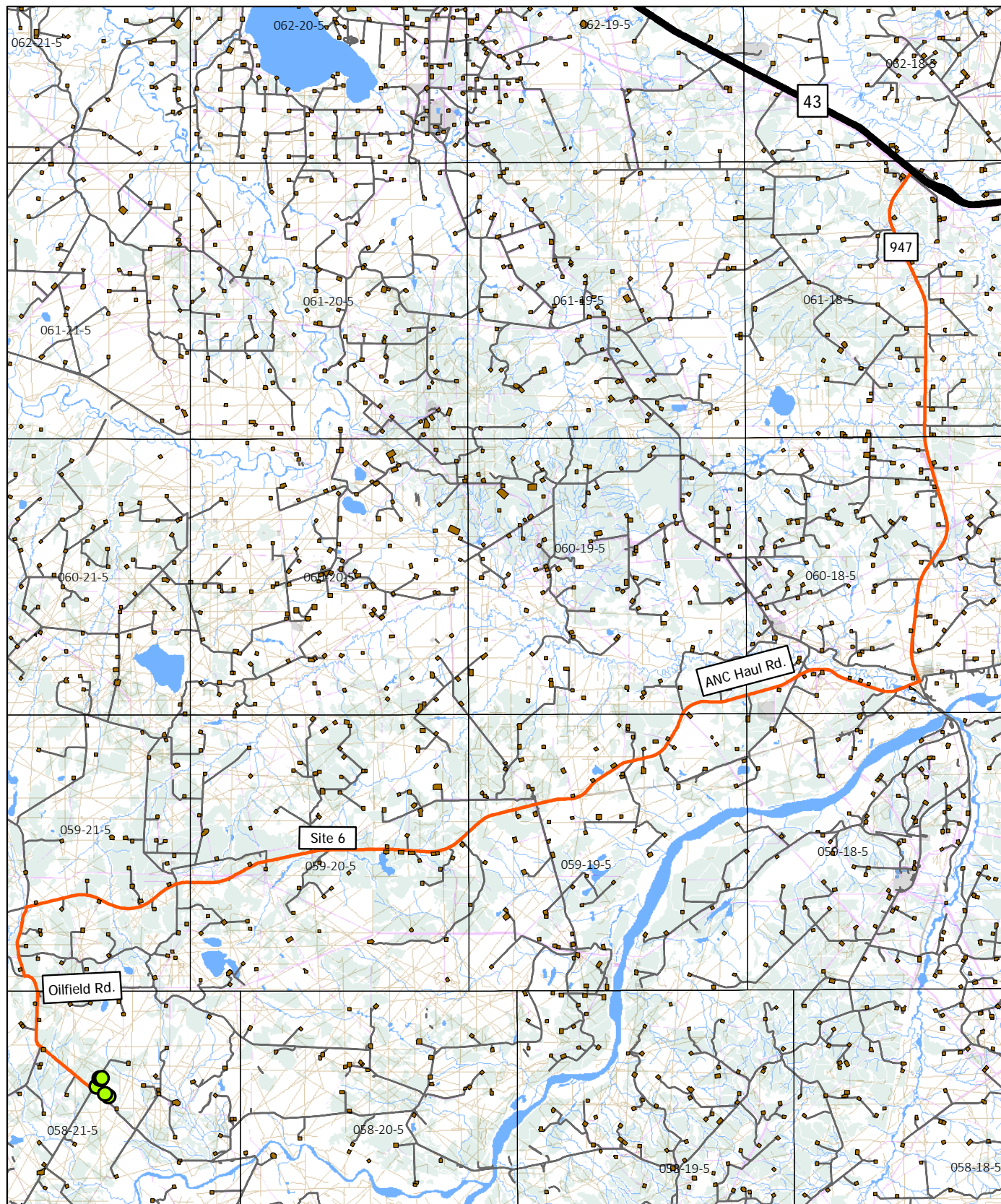
Section 21

Township 58

Range 21

Meridian W5

Site-7 Access



Herbicide Site-7

Scale 1:5,200

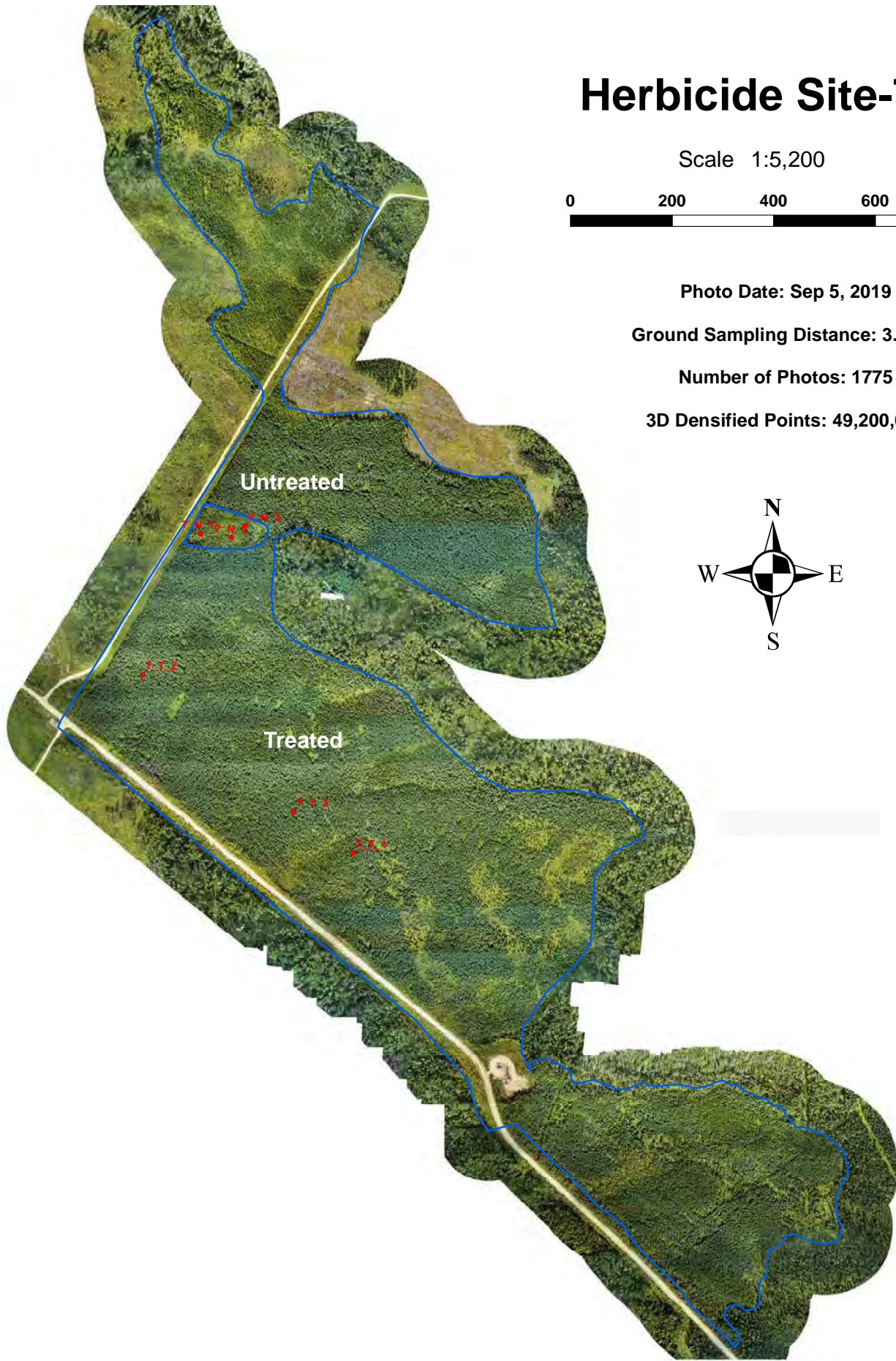


Photo Date: Sep 5, 2019

Ground Sampling Distance: 3.4 cm

Number of Photos: 1775

3D Densified Points: 49,200,000



BLOCK HISTORY

Harvested by:
ANC Timber Ltd.

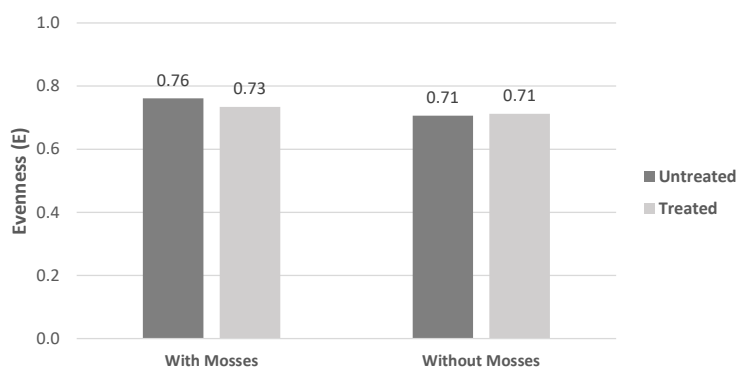
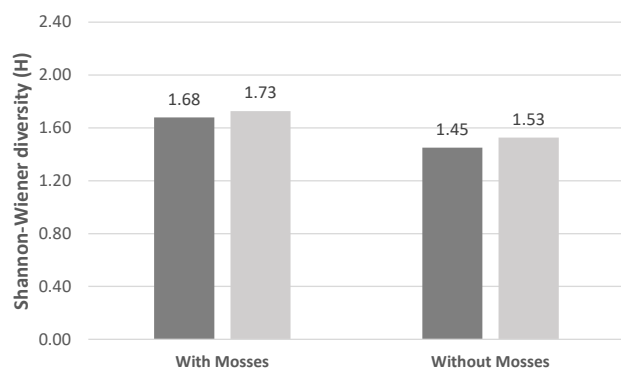
Year harvested:
1992/93

Age at sampling:
27 years

		TREATED	UNTREATED
SITE PREPARATION	1992	Disk	Disk
PLANTING STOCK	1993	<i>Species</i>	Sw
		<i>Type</i>	Plant
		<i>Size</i>	415B
		<i>Density</i>	1761
TENDING	1996	<i>Product</i>	Glyphosate
		<i>Rate</i>	2136
		<i>Method</i>	Aerial

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
<i>% change¹</i>	121%	-100%	122%	-100%	-35%

¹ % change = (Treated – Untreated volumes)/Untreated volume

SITE 8

EFFECTS DEMONSTRATED

Herbicide treatments had a small effect on species richness, a small negative effect on biodiversity indices of non-tree species, and a large effect on tree volumes and composition.

- Species richness decreased from 38 species in the untreated portion to 36 in the treated portion (change = -2).
- Species diversity (H) decreased in the treated portion, although the magnitude of change was much smaller when mosses were excluded from the calculation.
- Likewise, evenness (E) of non-tree vegetation decreased in the treated portion, but only when mosses were included in the calculation. This result suggests that increased dominance of mosses in the treated portion may have driven much of the decline in diversity (H), while changes to the remaining non-tree vegetation were comparatively small.
- Conifer volumes increased by more than 550% and deciduous volumes decreased by 99% in the treated portion. Overall volume of all tree species was nearly unchanged, increasing by only 4%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Travel via Highway 16 and Wolf Lake Road.

1. Get on the Wolf Lake Road approximately 21.6 km east of Secondary Highway 748 – east of Edson.
2. Travel 60.5 km south on Wolf Lake Road.
3. Turn east onto oilfield road (marked as a gas plant turnoff).
4. Travel 5.2 km to Site 8.

[Note: from Site 8, continue to Site 9]

COORDINATES

LAT/LONG (WGS 84)

Latitude N53° 10.116'

Longitude W115° 52.119'

UTM (NAD 83)

Northing 5891623

Easting 575627

Zone 11N

ATS

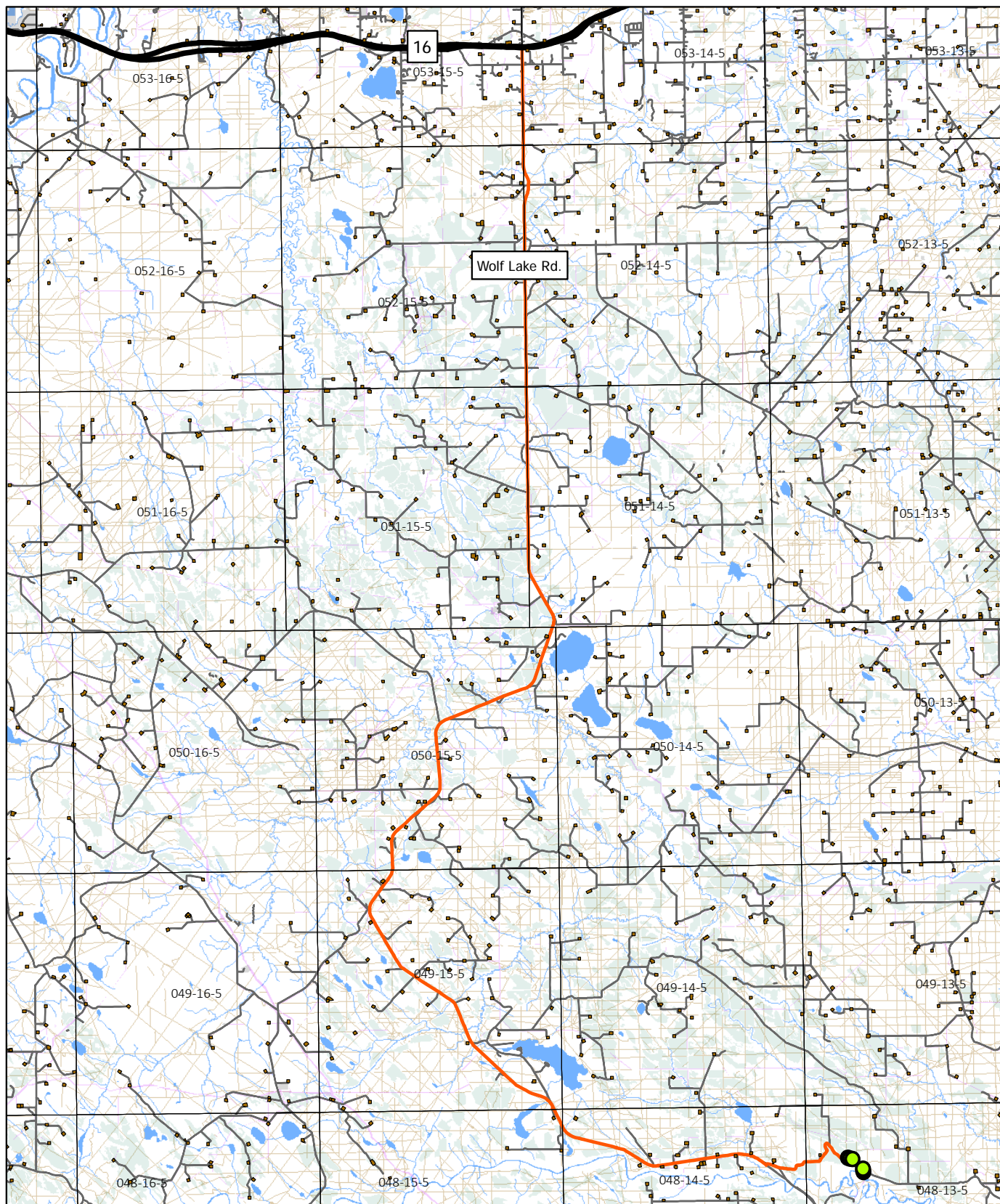
Section 29

Township 48

Range 13

Meridian W5

Site-8 Access




NAD83 UTM11N |

Township-Range-Meridian Grid

 Plots

 Well Block

 Cutblock

 Industrial Site

 Pipeline

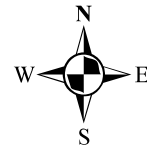
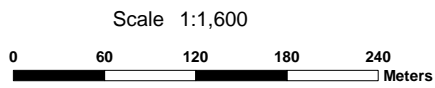
 Road

 Cutline



Photo Date: Sep 13, 2019
Ground Sampling Distance: 3.6 cm
Number of Photos: 557
3D Densified Points: 17,300,000

Herbicide Site-8



BLOCK HISTORY

Harvested by:
ANC Timber Ltd.

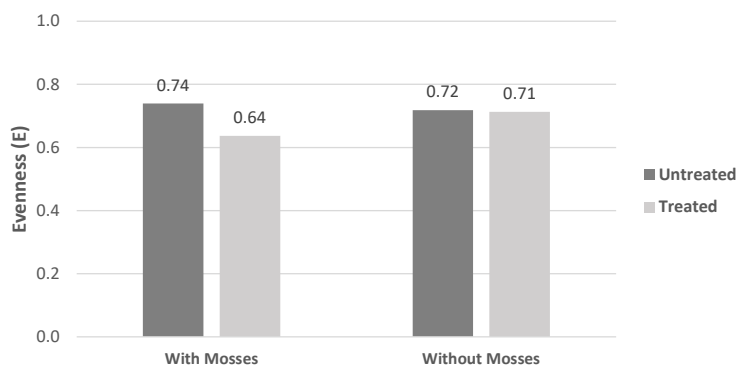
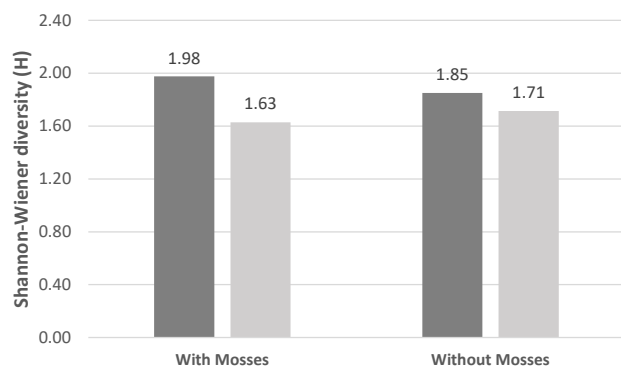
Year harvested:
1995/96

Age at sampling:
24 years

		TREATED		UNTREATED
SITE PREPARATION		1997	Mound	Mound
PLANTING STOCK	1998	Species	Sw/Pl	Sw/Pl
		Type	Plant (Sw)/LFN (Pl)	Plant (Sw)/LFN (Pl)
		Size	415B	415B
		Density	1276	1276
TENDING	1999	Product	Glyphosate	-
		Rate	2136/1568	-
		Method	Aerial	-
	2006	Product	Triclopyr	-
		Rate	3230	-
		Method	Basal bark	-

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
% change ¹	556%	-99%	556%	-99%	4%

¹ % change = (Treated - Untreated volumes)/Untreated volume

SITE 9

EFFECTS DEMONSTRATED

Herbicide treatments had a small effect on species richness, a negative effect on biodiversity indices of non-tree species, and a large effect on tree volumes and composition.

- Species richness increased from 29 species in the untreated portion to 33 in the treated portion (change = +4).
- Plots in the treated portion had relatively large decreases in both species diversity (H) and evenness (E) of non-tree vegetation. In both cases, the magnitude of decreases was smaller when mosses were excluded, yet they remained large. These findings suggest that the diversity and evenness of non-tree vegetation declined and mosses accounted for only part of this decline.
- Conifer volumes increased by 230% and deciduous volumes decreased by nearly 100% in the treated portion. Overall volume decreased by 30%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Directions from Highway 16:

Travel via Highway 16 and Wolf Lake Road.

1. Get on the Wolf Lake Road approximately 21.6 km east of Secondary Highway 748 – east of Edson.
2. Travel 60.5 km south on Wolf Lake Road.
3. Turn east onto oilfield road (marked as a gas plant turnoff).
4. Travel 5.2 km to Site 8.

Directions from Site 8:

5. Stay on oilfield road on which Site 8 is located and travel 1.9 km to wellsite road.
6. Turn north onto well site road.
7. Travel north then west 1.7 km on well site road. At 90° turn (turn goes to north) get onto pipeline and walk approximately 250 m to Site 9.

COORDINATES

LAT/LONG (WGS 84)

Latitude N53° 10.564'

Longitude W115° 51.033'

UTM (NAD 83)

Northing 5892473

Easting 576824

Zone 11N

ATS

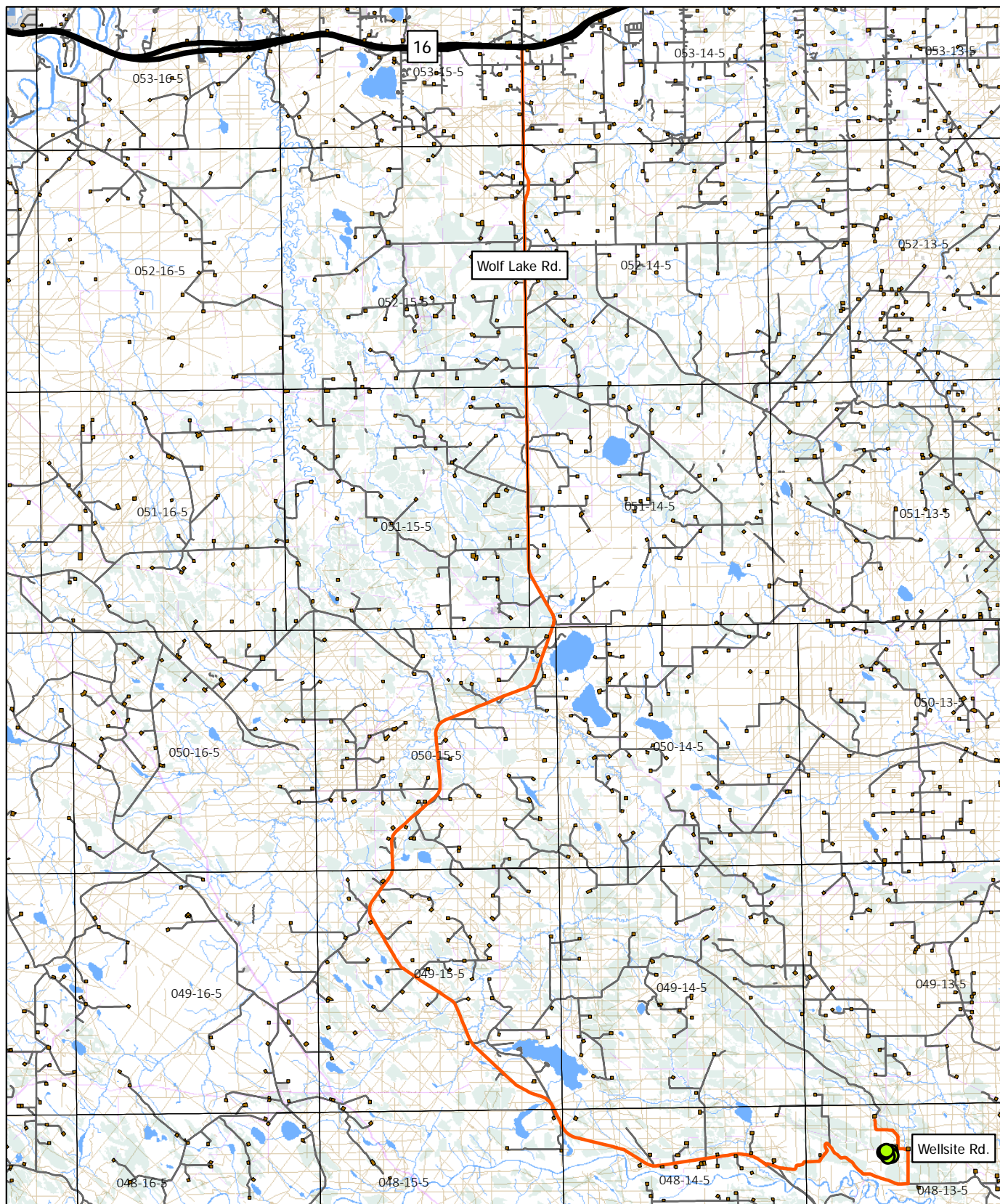
Section 28

Township 48

Range 13

Meridian W5

Site-9 Access



NAD83 UTM11N |
Township-Range-Meridian Grid



Plots



Cutblock



Pipeline



Road



Well Block



Industrial Site



Cutline

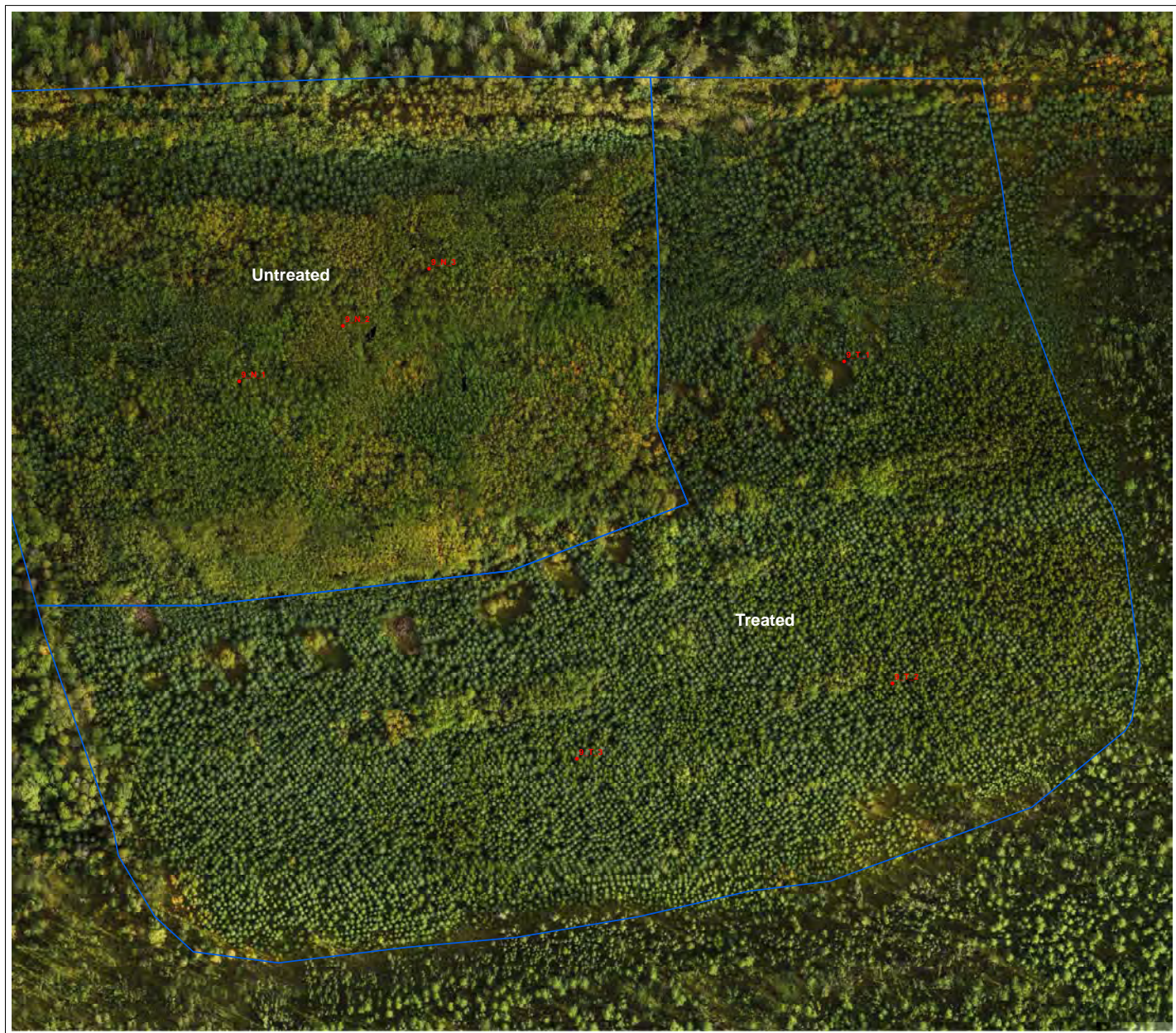
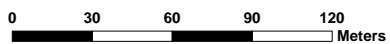


Photo Date: Sep 13, 2019
Ground Sampling Distance: 2.8 cm
Number of Photos: 339
3D Densified Points: 38,000,000

Herbicide Site-9

Scale 1:900



BLOCK HISTORY

Harvested by:
ANC Timber Ltd.

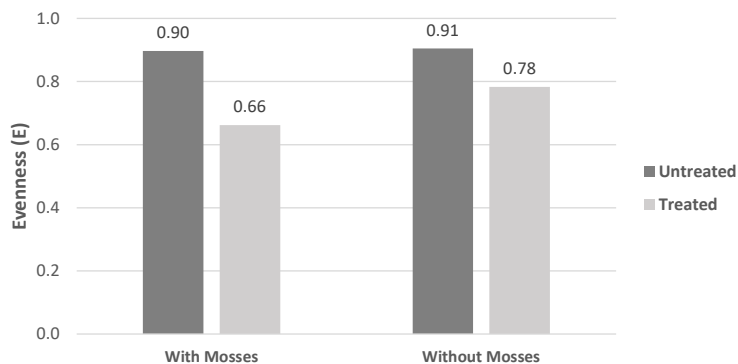
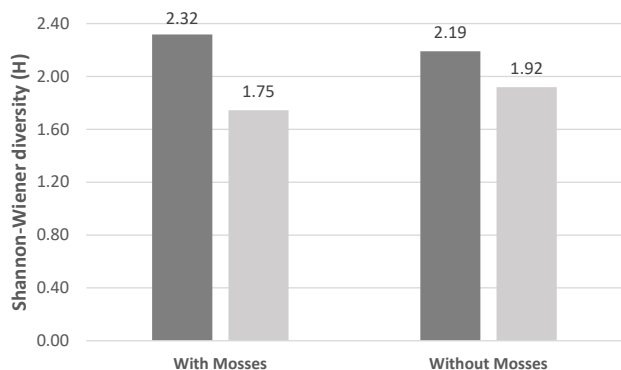
Year harvested:
1996/97

Age at sampling:
23 years

		TREATED	UNTREATED
SITE PREPARATION	NA	-	-
PLANTING STOCK	1996	<i>Species</i>	Sw
		<i>Type</i>	Plant
		<i>Size</i>	415B
		<i>Density</i>	1775
TENDING	1998	<i>Product</i>	Glyphosate
		<i>Rate</i>	2136
		<i>Method</i>	Aerial
	2007	<i>Product</i>	Glyphosate
		<i>Rate</i>	1424
		<i>Method</i>	Backpack

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
% change ¹	230%	-99%	230%	-97%	-30%

¹ % change = (Treated - Untreated volumes)/Untreated volume

SITE 10

EFFECTS DEMONSTRATED

Herbicide treatments had a minimal effect on species richness and a positive effect on biodiversity indices of non-tree species; deciduous volumes decreased while conifer volumes increased.

- Species richness decreased from 32 species in the untreated portion to 31 in the treated portion (change = -1).
- Species diversity (H) and evenness (E) of non-tree vegetation increased in the treated portion, and the magnitude of these changes remained the same when mosses were excluded from the calculation. This findings indicate that non-tree vegetation became more diverse in the treated portion, and that this increased diversity was not due simply to increased moss cover.
- Conifer volumes—mainly merchantable species—increased by 204% in the treated portion. Deciduous volumes decreased in the treated portion: interestingly, there total aspen volume in the untreated portion was much lower than the other sites, and white birch and balsam poplar accounted for more of the decrease in total deciduous volume than at other sites. Overall volume increased by 18%.
- At the project level, feathermosses were much more common (23.7%) in treated plots. Wild sarsaparilla, low bush-cranberry and oak fern were significantly more common in untreated plots, but the average difference in cover was low (5% or less). The remaining indicator species (bracted honeysuckle, tall lungwort, dewberry and wild red raspberry) did not have significant differences.

HOW TO GET THERE

Travel via Highway 43 and Suncor Simonette Road.

1. From the Highway 43 – Highway 49 junction in Valleyview proceed 34.3 km to the Suncor Simonette Road.
2. Turn west onto the Suncor Simonette Road.
3. Travel 26.1 km on Suncor Simonette Road to Rio Alto Road.
4. Turn east onto Rio Alto Road.
5. Travel east and south on Rio Alto Road for 16.8 km to Canfor 2000 Road.
6. Turn east onto Canfor 2000 Road.
7. Travel 3.2 km to Site 10.

COORDINATES

LAT/LONG (WGS 84)

Latitude N54° 32.438'

Longitude W117° 26.794'

UTM (NAD 83)

Northing 6043767

Easting 471119

Zone 11N

ATS

Section 17

Township 64

Range 23

Meridian W5

Site-10 Access

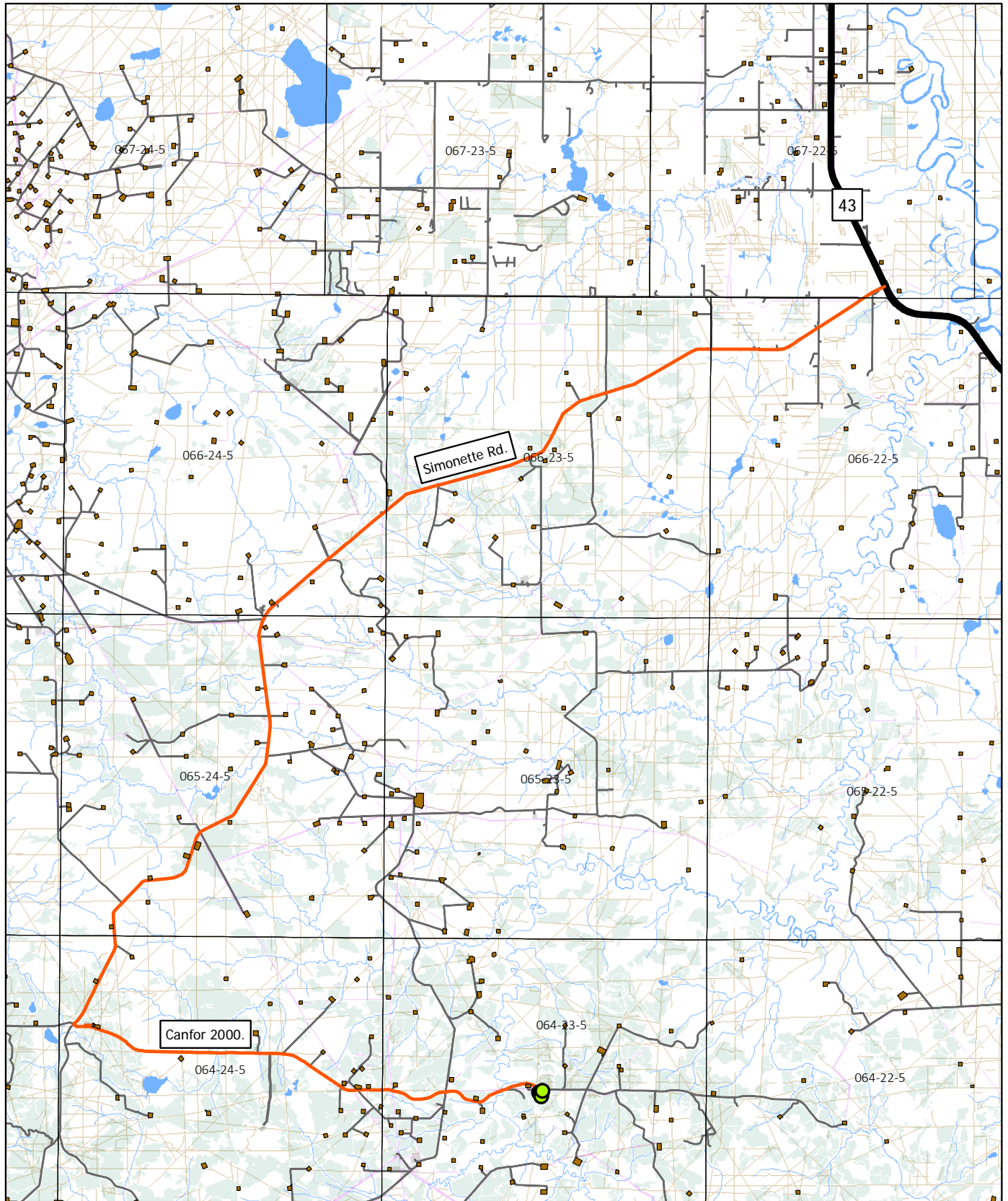
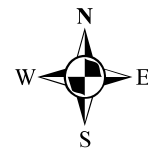
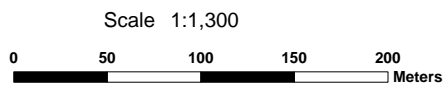




Photo Date: Sep 6, 2019
Ground Sampling Distance: 3.1 cm
Number of Photos: 485
3D Densified Points: 62,700,000

Herbicide Site-10



BLOCK HISTORY

Harvested by:
Canadian Forest Products Ltd.

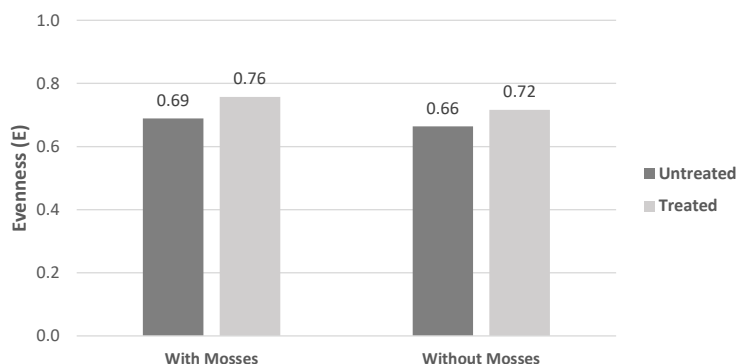
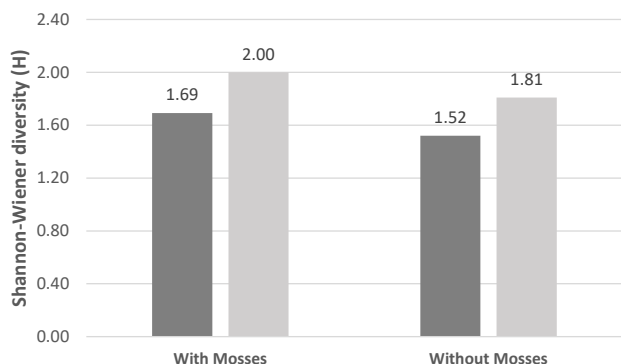
Year harvested:
1992/93

Age at sampling:
27 years

		TREATED	UNTREATED	
SITE PREPARATION	1993	DIPO	DIPO	
PLANTING STOCK	1993 (14.3 ha)	Species	Sw	Sw
		Type	Plant	Plant
		Size	313B	313B
		Density	1523	1523
	1994 (9.6 ha)	Species	Sw/Pl	Sw/Pl
		Type	Seed	Seed
		Size	NA	NA
		Density	Unknown	Unknown
	1999	Species	Sw	Sw
		Type	Plant	Plant
		Size	415B	415B
		Density	820	820
TENDING	1999	Product	Glyphosate	-
		Rate	2136	-
		Method	Aerial	-

"NA" indicates no data • "-" indicates no treatment • Gray indicates remedial/follow-up treatments

BIODIVERSITY OUTCOMES



FIBRE VOLUME OUTCOMES

OUTCOME	MERCH. CONIFER VOLUME (SW+PL)	MERCH. DECIDUOUS VOLUME (AW)	ALL CONIFER SPECIES VOLUME	ALL DECIDUOUS SPECIES VOLUME	ALL TREE SPECIES VOLUME
% change ¹	204%	-91%	78%	-93%	18%

¹ % change = (Treated - Untreated volumes)/Untreated volume

APPENDIX

BIODIVERSITY OUTCOMES: ALL SITES

Table A1. Mean Shannon-Wiener diversity (*H*) at each site. Standard deviations are provided in parentheses.

SITE	SHANNON-WIENER DIVERSITY (<i>H</i>)			
	With Mosses		Without Mosses	
	<i>Untreated</i>	<i>Treated</i>	<i>Untreated</i>	<i>Treated</i>
1	1.66 (0.13)	1.61 (0.16)	1.56 (0.14)	1.42 (0.27)
2	0.92 (0.46)	1.42 (0.24)	0.8 (0.55)	1.23 (0.14)
5	1.71 (0.14)	1.66 (0.11)	1.48 (0.23)	1.45 (0.09)
6	2.02 (0.41)	1.59 (0.02)	1.94 (0.37)	1.36 (0.04)
7	1.68 (0.15)	1.73 (0.11)	1.45 (0.17)	1.53 (0.2)
8	1.98 (0.15)	1.63 (0.17)	1.85 (0.13)	1.71 (0.34)
9	2.32 (0.15)	1.75 (0.47)	2.19 (0.19)	1.92 (0.29)
10	1.69 (0.09)	2.00 (0.09)	1.52 (0.17)	1.81 (0.17)

Table A2. Mean evenness (*E*) at each site. Standard deviations are provided in parentheses.

SITE	EVENNESS (<i>E</i>)			
	With Mosses		Without Mosses	
	<i>Untreated</i>	<i>Treated</i>	<i>Untreated</i>	<i>Treated</i>
1	0.76 (0.05)	0.74 (0.02)	0.74 (0.06)	0.73 (0.05)
2	0.56 (0.19)	0.66 (0.04)	0.51 (0.22)	0.67 (0.07)
5	0.77 (0.03)	0.81 (0.04)	0.71 (0.06)	0.79 (0.05)
6	0.8 (0.08)	0.76 (0.05)	0.79 (0.08)	0.71 (0.07)
7	0.76 (0.05)	0.73 (0.04)	0.71 (0.04)	0.71 (0.06)
8	0.74 (0.05)	0.64 (0.05)	0.72 (0.05)	0.71 (0.1)
9	0.9 (0.01)	0.66 (0.14)	0.91 (0.02)	0.78 (0.09)
10	0.69 (0.07)	0.76 (0.01)	0.66 (0.11)	0.72 (0.04)



FOREST GROWTH
ORGANIZATION OF WESTERN CANADA